

IN THE SPECIFICATION:

Please delete the following paragraphs:

Page 3: Please delete the paragraph beginning at line 5 and extending through line 23 of Page 3.

Pages 3 & 4: Please delete the portion of the paragraph beginning at line 26 of Page 3 and extending through line and extending through line 7 of Page 4.

Page 4: Please delete the paragraph beginning at line 8 and extending through line 22 of Page 4.
Please delete the paragraph beginning at line 23 and extending through line 25 of Page 4.

Pages 4 & 5: Please delete the paragraph beginning at line 26 of Page 4 and extending through line 14 of Page 5.

Page 6: Please delete the paragraph beginning at line 5 of Page 6, and extending through line 26 of Page 6.

Pages 6 & 7: Please delete the paragraph beginning at line 27 of Page 6 and extending through line 10 of Page 7.

Please insert the following paragraphs:

Page 10: Immediately after the heading at line 4, "Detailed Description of the Preferred Embodiments", please insert the following paragraphs:

- - Throughout this disclosure, including in the claims, the expression "beam control data" denotes data (whether in vector format or pixel format) that directly determines a configuration (or sequence of configurations) of beam control hardware that in turn determines what pattern is imaged on a target by a pattern generation system in response to a set of image

data. The pattern generation system of the invention receives raw image data and generates beam control data in response thereto, typically with an intermediate step of generating optimized hierarchical image data from the raw hierarchical data, and generating the beam control data in response to the optimized hierarchical image data. The term "optimized" is used in a broad sense to denote "improved" (e.g., embodying an improved combination of properties, such as reduced data volume to be transferred to the graphics engine, and ability to be converted to beam control data with acceptably low processing time) as well as "improved to the maximum degree" (e.g., embodying the best possible combination of the relevant properties). In one example, the pattern generation system of the invention receives and rasterizes a set of hierarchical image data (indicative of a two-dimensional bit map) to generate a set of beam control data (in pixel format) determining a sequence of pixels to be written to the target during raster scan. - -

- - One aspect of the inventive method is a method for generating beam control data in response to hierarchical image data. In a class of preferred embodiments, the invention rasterized hierarchical image data indicative of hierarchical CAD designs, such as designs in the conventional GDS-II format. A hierarchical design groups together (in an entity known as a "cell") data indicative of a feature (or set of features) that is to be repetitively placed in different positions on the layout (e.g. by iterating over the cell with appropriate offsets indicative of different locations on the layout). A cell of a hierarchical design can be "simple" in the sense that it consists of data that determines a repeated feature or feature set (but does not include or refer to another cell), or it can be "complex" in the sense that it includes a reference to another cell (which cell can, but need not, be included within the complex cell) and optionally also data that determines a repeated feature or feature set (without including or referring to another

cell). - -

- - A set of hierarchical image data includes one or more "primary" cells (each determining a feature or feature set that is repeated on the layout), and also additional data. The additional data includes data indicative of non-repeated features of the layout, and data referring to primary cells. Each primary cell can itself include references to one or more cells (denoted herein as secondary cells). Similarly, each secondary cell can include references to one or more cells (denoted herein as tertiary cells), and so on for higher levels of the hierarchy. If no primary cell includes a reference to a secondary cell, we shall refer to the overall set of hierarchical data as "two level" hierarchical data (which determines a layout having two-level hierarchy). If at least one primary cell includes a reference to a secondary cell, we shall refer to the overall set of hierarchical data as "N-level" hierarchical data (where N is greater than two) which determines a layout having N-level hierarchy. In contrast with hierarchical image data, "flat" format image data (determining a "flat" layout) includes no primary cell. - -

- - The expression "cell instantiation" is used herein to denote a reference to a cell indicating that a cell is to be copied to a particular location on the layout. Such location is typically denoted by an offset. - -

- - Hierarchy becomes inevitable due to the increasing number of features in typical IC layouts, and the shrinking size of critical dimensions of typical features (e.g., gate size) and the need to process correction management schemes that try to facilitate the physical reduction of critical dimensions by adding serifs and scatter bars. Hierarchical design reflects the congruent structure of repetitive building blocks of IC layout. A DRAM or FPGA (field-programmable gate array) device, for example, can define a flat-format count greater than 10^9 features. With 8

to 10 bytes per geometry, such a design, when implemented with a flat layout, imposes hard bandwidth problems when raw image data indicative of the design is communicated from a storage device to a raster engine. The inventors have recognized that it would be desirable to implement such a design as a hierarchical design (typically having N-level hierarchy, where N is greater than two) rather than a flat design, since the only new piece of information per cell instantiation is the cell's offset on the layout, so that communicating this offset is enough. Compaction factors of hierarchical designs scale proportionally with the number of cell instantiations. Therefore communicating a cell only once to a graphics engine (along with the relevant offset per instantiation) decreases the required communication bandwidth dramatically. - -

- - The trend of growing file size for lithographic data is likely to outpace the increase of data transfer rates in pattern generation systems used for lithography. Relying on ample processing power and larger available memories rather than on fast transfer rates offers a robust and workable paradigm. The inventors have recognized that it is therefore desirable to reduce the data volume that must be transferred to graphics engines of pattern generation systems such that chunks of repeated data are transferred only once to a graphics engine and kept in memory of the graphics engine until each chunk is repeatedly referred to. In typical embodiments, the present invention browses the hierarchical data structure of image data (which can be in GDSII format) which contains geometry data determining a pattern to be imaged on a target, and identifies the most significantly repeated cells of image data. The image data is then compressed in the sense that each of its most significantly repeated cells is transferred only once to the graphics engine (for caching in memory of the graphics engine). Subroutine call commands are also transferred

to the graphics engine so that the graphics engine can process the subroutine call commands to retrieve each cached cell from memory more than once (at appropriate times). The graphics engine thus inflates the compressed data transferred to it in accordance with the invention, typically with a large inflation factor due to the typically high number of instantiations of cached cells. Transferring this data only once, caching a subset of the transferred data in the graphics engine, and recalling the cached data repeatedly unclogs the download bottleneck. - -

- - More specifically, the present invention decreases the volume of image data that must be transferred to a graphics engine (e.g., raster engine) by determining a set of N-level hierarchical image data, where N is greater than one (preferably N is greater than two), transferring the hierarchical image data to the graphics engine ("GE"), and caching cells of the hierarchical image data in a memory of the GE. The GE executes subroutine call commands in response to elements of the hierarchical image data, which can be either portions of cached cells, or non-cached elements of the hierarchical image data. Each subroutine call command retrieves a cached cell (from memory of the GE) and generates beam control data (for imaging a pattern determined by the cell, at a location on the target indicated by an offset) in response to the retrieved cached cell and data indicative of the offset. In preferred embodiments, the beam control data is in pixel format, but it can alternatively be in vector format. - -